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THE JOURNAL
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# FRED HOYLE'S UNIVERSE*

by RALPH E. WILLIAMSON

IF you've been listening to Dr. Hoyle's series of talks on the Nature of the Universe, you may want the answers to some questions: Are there other living beings in the universe? Is matter really being created all the time? How do we know? Can we even be certain of the distance to the nearest star? And who is Fred Hoyle? Should we believe everything he says?

Hoyle is a fellow of St. John's College at Cambridge University. Brilliant and highly trained in mathematics and astronomy, he is one of the present representatives of a long line of distinguished scientists from Cambridge.

It may surprise you, then, to learn that many scientists have severely criticized Dr. Hoyle's current series of lectures. Everyone will agree that his presentation was first-rate—his voice pleasing and authoritative. The criticisms have to do with the deeper issue of the truth or falsity of the material discussed. Hoyle concerned himself with a great diversity of astronomical subjects: the earth, the solar system, the multitude of stars known as our galaxy, what goes on inside the stars, what happened in the remote past, and what will happen in the unimaginably distant future. What he did not do was to give any inkling of how these things are found out, or of the limits

*_Editorial Note_—This is a transcript of comments on the series of lectures by Fred Hoyle on the Nature of the Universe presented by the Canadian Broadcasting Corporation. These comments were broadcast over the Trans-Canada network of the C.B.C. on June 27, 1951.

Fred Hoyle's book, _The Nature of the Universe_, is published by Blackwell, Oxford, Eng., price 5_s._, Toronto: Copp Clark Co.

of our present actual knowledge. In this way he carried us over much more territory, to be sure, but at rather a high price.

In the ten years or so in which Hoyle has been engaged in scientific research, he has written a number of papers, highly theoretical in nature, having to do with the past and the future of stars and galaxies. But to my knowledge, he has had no real experience with handling the large telescopes which make modern astronomy possible.

It is one thing to try to sell a novel idea to a group of scientists, who are equipped with the experience and mathematical training necessary to determine whether the idea is worth considering further. It's very different when one talks to the non-scientific world, and gives what is presumably an impartial and authoritative account of what is currently held to be true in astronomy. The majority of astronomers are genuinely in love with their work, and they want any who hear about it to have a true picture of its intrinsic beauty and fascination. This lies at the root of the general dissatisfaction of astronomers with what Hoyle has said. It's almost a tradition that a scientist speaking to the public makes every effort to be impartial in his presentation of scientific fact. Hoyle has not done that.

Now, you may ask, how does an astronomer work, how does he decide what the scientific facts are?

There are perhaps a thousand astronomers, men and women, throughout the world. Some of them are concerned primarily with using great telescopes to measure the quantity and quality of light from the stars. Results of their efforts may appear as lists, in the technical journals, of the brightnesses of stars, or their speeds, or the elements found in their atmospheres. To avoid errors, the most important observations are repeated independently. In this way, a body of fact is built up.

Other astronomers, sometimes referred to as theoretical astrophysicists, will make inferences from these observations, in an attempt to answer such questions as: is there material in the space between the stars—what is it like—what is its destiny? Or again, knowing the mass, the diameter, and brightness of a star, what can we say about the conditions inside? And so on. You can readily see that the interpretations, while in a way the most exciting part, are also likely to be much less trustworthy. When an interpretation of observations has been assessed critically by many theoretical men, and subjected

to many more observational tests, and still comes through with no contradictions, we can allow it a place as a valid scientific fact.

I think you will see that we must develop certain working hypotheses as we go along, embodying a large amount of scientific material which is currently accepted at face value, but which has not the status of final certainty. Our current ideas of the size of our own galaxy belong in this class. Distances, sizes, and compositions of the other galaxies, or spiral nebulae as they are called, are highly probable but not certain. You may recall Dr. Hoyle's graphic scale model of the universe, in which he asked us to imagine each spiral nebula (approximate dimensions, a hundred thousand light-years) as a bee. The average distance between bees should be about three yards, and then that part of the universe detectable with the largest telescopes would be about a mile across. You remember that I said that this is only a working hypothesis. And we are now far less certain of it than we were even when Dr. Hoyle recorded his lectures. Within the last few weeks Dr. Fritz Zwicky, of the Mount Wilson and Palomar Observatories, has published results of observations which strongly suggest that this whole picture is two or three times as big as it should be. If further observations substantiate this, Hoyle's ideas on the continuous creation of matter (among a great many other things) will have to be seriously reconsidered.

Dr. Hoyle gave a great deal of time to the interesting question of what goes on beneath the surface of the stars. He quoted the temperature at the centre of the sun as 20,000,000 degrees Centigrade, and added that "it is an interesting thought that we know more about the interior of the sun than we do about what goes on inside a tea-kettle of boiling water." But even while he was preparing his broadcast material, a young graduate student of mine at the University of Toronto, and another student at Princeton, working independently, both turned up the result that another nuclear reaction is probably the controlling factor in the sun's central temperature, making it more likely to be 16 million than 20 million degrees. Now a comparable error in the boiling point of water would put it at 77 degrees Fahrenheit, not 212. No, I'm afraid we don't really know more about the inside of the sun than we do about the inside of a boiling tea-kettle.

To see how much of Hoyle's material could be taken as honest fact, I went through each of his lectures, jotting down the time he

devoted, first, to incontrovertible astronomical fact; second, to working hypotheses, and third, to essentially unproved theories. I found that the subject matter consisted of about 20 per cent. pure fact, about 30 per cent. of working hypotheses, and the remaining 50 per cent. was devoted to pure, untested theory. It will not surprise you, at this point, to hear that the theory was, almost without exception, Hoyle's own.

Now a man is surely at his best when talking about what is nearest to his ways of thinking, but the great disservice which Hoyle did to the intelligent listener is that he afforded no clue as to what was fact and what were his own ideas, not shared by other scientists. If we exclude Velikovsky's maunderings, Hoyle has committed the most glaring example of this kind of thing in modern times.

Perhaps the most exciting question which Hoyle discussed is whether there are inhabited worlds in the universe. Let us begin by getting our facts straight. Our sun, a mediocre star, has nine planets moving around it, deriving light and warmth from it. Of these, the earth supports life, but the only other possibility in our solar system is Mars. There is rather strong evidence that it may have some vegetation, but the evidence is that there is probably no animal life. And other stars than the sun are so far away that there is no chance of seeing or photographing any possible planets they may have. You may wonder how we can be sure that there are other planetary systems in the galaxy. The truth is—we just plain can't. Then what of Hoyle's estimate of 100,000 planetary systems in our galaxy? (In his BBC series, by the way, he put the number at one million; I wonder what he will say next year?) Well the answer is very simple. Hoyle ascribes the origin of the solar system to material blown off in a supernova explosion of a hypothetical companion star of the sun in the dim past. If we wish to believe this, we can make estimates about the number of solar-type stars in the galaxy, and how many of them would have companions which could suffer a supernova explosion and what fraction of these would leave material of the right amount, and so on. But the *if* is a big one. Currently there are at least a half-dozen alternatives to Hoyle's theories, many of them better worked out, and more likely to be right.

Another interesting idea of Hoyle's has to do with something more vast than our solar system: nothing less than the whole universe.

That branch of astronomy which considers the problems of what the universe itself was, is, and is going to be, is called cosmology. The crucial point of Hoyle's theory of cosmology is that the universe is still being created. The idea that matter is being born right now at this very minute, not only far off in the vast depths of space, but right in your own room, perhaps over in the corner by the radio, is an exciting one. If this process goes on, it is far too slow to detect by laboratory measurements, because it amounts to only one atom per century in a space the size of a room. Whether this idea of Hoyle's is right or not must be decided by the limited knowledge we have of the sizes, distances, and speeds of the spiral nebulae. As I indicated earlier, we may be due for a revision of our ideas, thanks to the work of Zwicky with the Palomar telescopes.

Another important consideration in this matter of cosmology, which Hoyle hardly touched at all, is the large number of other possible theories. The proponents of these theories would hardly agree with Hoyle's judgment of his own theory of continuous creation, when he said, ". . . by and large, I think that our present picture will turn out to bear an appreciable resemblance to the cosmologies of the future. . . . Continuous creation I expect to play an important role. . . ."

Astronomers are usually inclined to smile at this sort of self-adulation; one is rather forcibly reminded of Don Marquis' little character, Warty Bliggins. Warty Bliggins, when mildly chided for his assumption that the universe was created for him, and asked what he had done to deserve so much, replied, "Ask rather, what has the universe done to deserve me?" Most astronomers would prefer a concept in which any one man—even mankind—plays a less presumptuous part. And no scientist, however great and original his contributions, could honestly say more than the great Newton did of his own work: "I do not know what I may appear to the world; but to myself I seem to have been only like a boy, playing on the seashore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

# THE METEOR CRATERS IN HÉRAULT, FRANCE

By C. Luplau Janssen

IN the following I shall try to give some information of a crater field, which has recently been discovered in southern France. The discovery was first announced by Mrs. Bernard Gèze and André Cailleux in the *Comptes rendus* of the Paris Academy in April 1950. Having read this notice, I resolved to visit these craters in connection with a stay at the Observatory of Pic-du-Midi in September 1950. It is only a few hours by train from Bagnères-de-Bigorre, near Pic-du-Midi, to Béziers, which is situated near the crater field in question, in a region with a rather dense population and easily reached by rail and motor. In view of the great interest which formations of this kind have aroused, I should think that a little more detailed description, as a supplement to the discoverers' report, should be of interest. The following account is based on the description given in the article published by the discoverers and on my own observations. Curiously enough the Cabrerolles Crater presents some similarity to a very well-known lunar crater, a circumstance which has not been commented upon by the two French discoverers.

It is worth while to remark, as has also been pointed out by the discoverers, that these craters were first detected through an examination of some aerial photographs of the region in question, by the stereoscopic method. We remember that the Chubb Crater, investigated by V. B. Meen, was first discovered on aerial photographs. Thus, we must be aware of the high importance of aerial surveys of the terrestrial surface when we are searching for phenomena of this kind. This line must be followed closely in the future.

As we cannot suppose that the general character of the region in question is generally known, some introduction should be given. Our crater field is situated in the department Hérault, which is in southern France; it takes its name from the river Hérault, which, coming from the "montagne noire", flows into the Mediterranean Sea. The south-eastern part of Hérault is a part of the Languedoc plain, while the north-western half is occupied by the south-eastern

slope of the "montagne noire", which is connected with Auvergne. The capital of Hérault is the well-known university town of Montpellier; Béziers is another large town. The coastal plain as well as the slopes of the mountains are very fertile and completely covered by vineyards, a very great part of the wine consumed in France being produced here. The trunk line through Toulouse, Narbonne, Sète, Nîmes and Marseilles runs through Hérault. A secondary line starts from Béziers and runs to Bédarrieux, an industrial town producing cloth, linen and leather. A visitor to the crater field, which is situated in the villages of Faugères and Cabrerolles, should make his headquarters in the last named town where cars may be hired. The nearest railway station to the craters is Faugères on the line Béziers-Bédarrieux, but in Faugères no hotel accommodation is available and no cars can be hired. Naturally it is quite possible to reach Faugères by train and visit the craters on foot, but, as the terrain at some places is rather difficult, the walk is rather tiresome, especially in hot weather, and we think it better to cover the small distances (Bédarrieux, Faugères, Cabrerolles—15 km.) by means of a car hired in Bédarrieux. Cars may also be hired in Béziers, but here the distance is longer, approximately 45 km. Faugères is at an altitude of 258 metres above sea level, while Cabrerolles is situated roughly 50 metres higher. At once it must seem very unlikely that prehistoric craters should have been well preserved in a so intensively cultivated region, and this calls for an explanation. Actually we find the craters in a countryside just in the zone between the plain and the mountains. Here the mountains send long rocky "peninsulas" out in the plain. These rocky plateaus are not cultivated at all, their surfaces are left quite in their natural state, while the valleys between them are very fertile and well cultivated. The author is not a geologist, but even a very superficial geological experience allows him to state that great erosion has taken place in this country; further it is also evident that the rocks here belong to the pliocene age; we are dealing with schists. It is obvious that the rocky surfaces have been heavily attacked by air and water; the rocky "peninsulas" do not exhibit great irregularities. The French discoverers point out that we are dealing with a series of craters arranged on a line 5 to 6 km. long. The main crater, which is called "Le Clot", is

at the western end of a strip running from south-south-west towards north-north-west, on which one large crater and some small ones, especially in the neighbourhood of the village of Faugères, are arranged. I think that it will be wise to give here a translation of the very short French article published by the two French discoverers in *Comptes rendus de l'académie des sciences*, Paris, April 24, 1950, omitting the summary, which precedes it and some few lines at the end:

We know that craters which may be considered produced by the impact of great meteorites are rather seldom met with in terrestrial topography. Only eight cases are known.* But some depressions found by one of us near the eastern extremity of the slopes of the Black Mountains, seem to be of meteoric origin. The depression at Cabrerolles, called "Le Clot", to which our attention was first drawn through the examination of some aerial photographs, is situated approximately one km. to the south-south-east of the village and presents itself as a hole in the schists. It interrupts small ravines from the quaternary age, and its depth is approximately 50 metres, and it penetrates into the eroded soil, which probably is pliocene. It is quite circular with a diameter of 200 to 300 metres at the upper rim, while the diameter of the flat bottom is roughly 100 to 110 metres. The inner slopes are very steep, partly covered with broken stones (coarse gravel). Five km. from here to the east-north-east (300 metres from the railway station of Faugères) we find a similar crater, although smaller (diameter at the upper rim 50 to 60 metres, maximum depth 23 metres). This crater has been hollowed out of the schists, having penetrated the pliocene surface just at the upper edge of a deep quaternary ravine. Other similar depressions are also found in the immediate neighbourhood, two of them being situated just to the west of the village of Faugères (diameters: 45 to 50 metres and 50 to 65 metres, depths 28 metres and 20 metres), and one more to the north-east of the same village (diameter 45 to 50 metres, maximum depth 9 metres) and one or perhaps two 1400 metres to the north-north-east of the same village (the most certain one has a diameter of 15 metres and a depth of 5 metres), but as they are holes in the same strata of Devonian limestone, we cannot *a priori* exclude a karstic origin.

Several reasons support the supposition of the meteoric origin of these craters:

1. For the two first quoted craters a karstic origin is impossible, as they are hollowed out in pure silico-aluminous rocks and at distances of 600 to 1000 metres from the nearest limestone rocks, reckoned horizontally as well as vertically.

2. A very pronounced magnetic anomaly is found in the interior of the Cabrerolles crater and in its vicinity, the magnetic declination here attaining a value of 10°. . . . . .

These are the facts pointed out by the two French surveyors, and from this alone we may draw conclusions in favour of a meteoric

*It seems that the two authors do not know all the craters discovered up to the present. *L.J.*

origin. We are now going to supplement these short remarks with our own observations made in September 1950.

We started by rail from Béziers and got off at Faugères, which consists of a small group of houses along the side of the main road from Bédarrieux to Béziers and a rather large winery, the property of Mr. Noël Salles. The first thing to be done was to find the crater, which should be within 300 metres from the railway station. Therefore we asked the station-master for information. He seemed at first to know nothing of it. He had lived there for many years and he had never heard of holes of that kind, nor of any explorers. At last, as we asked if there were no holes at all in the vicinity, he burst out: "It must be the valley in which I collect mushrooms." We had, he said, only to climb the steep slope behind the village in order to reach it. We followed his directions and forced our way through a rather complicated scrub covering the slope of a very beautiful rocky hill. Although its height was only 100 metres or so, it was a rather troublesome ascent, but at last we reached the upper rim and were standing at the edge of a vast vineyard, but we could see nothing but vines and scrub. As we were just in the midst of the wine season, there were many people in the fields collecting the ripe grapes. We asked the nearest man and to our astonishment he answered at once: "It is just there behind those trees," pointing out some bushes 100 metres away. We hurried to the indicated place and suddenly we stood at the upper edge of a deep circular hole with very steep interior slopes. The sight was very remarkable as the hole is situated on the very slope itself in such a way that the uppermost point of the edge of the hole touched the horizontal line marking the upper edge of the slope, the plane of the rim of the crater having almost the same inclination as the slope. We found, that the dimensions of the crater were in full accord with those given by our French colleagues. The inner slopes were very steep (the inclination was 45° or so) and partly covered with scrub, but at many places the rock was visible, that is the slopes were covered with a number of large stones and very coarse gravel or stone bits. The bottom of the crater was flat and horizontal, some rather high trees were standing there and their tops were almost in the horizontal plane of the plateau above the slope. Much of the coarse gravel was also noticed in every uncultivated place in the vicinity of the crater, and many of these small

stones were of a kind of limestone much resembling marble-stone. This mineral did not seem to belong to the surface of the rock but to some thin stratum deep in the ground. I believe I saw such strata in both craters, but, as I am no geologist, this observation must be accepted with reservation. If it is correct it gives very strong support to the supposition of the meteoric origin of these craters. The white stone bits must have been ejected from the bottom of the hole. Naturally all the stones have been removed from the cultivated areas, we are here in an intensively cultivated region, where human activity has produced many disturbances, but the slope on which this crater is situated is not cultivated at all.

FIG. 1.—The Faugères Crater from the lower part of the rim.

Figure 1 is a view of the crater from the lower rim. The steepness of the inner slope is clearly shown, the high trees at the left are standing on the bottom of the hole. The dimensions are easily estimated when we use the height of Mrs. Luplau Janssen, who is standing at the upper rim, as a scale. The form of the crater is quite circular and the conditions of the slope bear testimony of a violent explosion. There cannot be the least doubt of the meteoric nature of this crater.

The view of this crater was very impressive, but it was nothing in comparison with that of the Cabrerolles crater, "Le Clot", which we visited later on the same day. As there is no hotel accommodation in Faugères, we had to finish our research in one day. After some adventures we reached Cabrerolles by car and located Mr. Jerôme Carattié, the owner of the land on which "Le Clot" is located. He knew nothing of the origin of the formation, but he drove us there, a distance of one km. from the village along the road to the west of the narrow Cabrerolles valley. He led us on foot up a sandy path along which some small bushes and low plants barely covered the rocky surface. After a walk of about 500 metres we suddenly stopped on the elevated rim of an astonishing hole in the plateau. We had reached the aim of our search. The crater was quite circular and the slopes seemed still steeper than in the case of the Faugères crater. The consistency of the soil was identically the same in both craters. The slopes presented some few blocks of stone and an enormous quantity of gravel. The dimensions were found to correspond exactly to those given by the French surveyors.

The depth from the rim is about 60 metres and the tops of some high trees standing on the bottom of the crater are considerably below the top of the rim. At places the inclination of the inner slope was nearly 60°. Also here the condition of the materials showed traces of a formidable explosion, and here again many bits of white limestone were lying on the ground. The rim was elevated some metres above the level of the plateau on which this crater is situated.

The bottom of the crater is flat, and here Mr. Carattié has arranged a small vineyard and garden. Figure 2 is a photograph of the bottom and of the inner slope. The proportion of the height

FIG. 2.—The interior of the Cambrerolles Crater.

of the trees to the height of the slope gives a fairly good impression of the size of the crater.

As we have already said, the crater is circular, presenting an elevated rim, but a closer examination of the latter reveals a very remarkable thing. The rim has some depressions, two of them being rather distinct. If we examine the surroundings we find that the crater overlies one or possibly two ravines torn out of the plateau on which "Le Clot" is situated. This leads us directly to the well known case of the Hyginus ridge on the moon where we also find a crater overlying a ravine. Just as in the case of the Cabrerolles crater the ravine is older than the crater, which completely interrupts it. Obviously, as the French geologists also say, the ravine at Cabrerolles is from the quaternary age, and this tells us that the crater is, astronomically, a recent formation; it should not be older than 10,000 years.

Figure 3 presents a contour map showing the interrupted ravines and also a cross section showing the present surface and the supposed former surface.

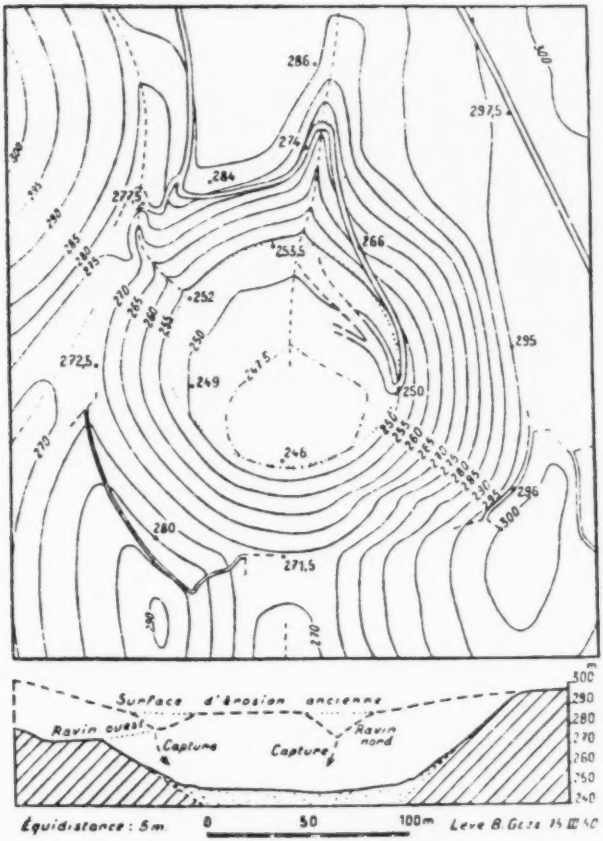



FIG. 3.—Map and cross section of "Le Clot", from "Comptes rendus de l'Ac. d. Sc.", Paris, 1950, p. 1535. Heights in metres above sea level.

We must confess that "Le Clot" to some extent is covered by vegetation, but it is easily seen that if the vegetation was removed, there would be a very close resemblance to the most typical meteor craters known. It is not easy to evaluate the significance of the strong magnetic anomalies observed. It may be that some iron

mass is hidden below the ground. The high magnetic declination is limited to the crater and its immediate surroundings, and this might give us some hints in this direction. I have not the least doubt that we are here dealing with a meteor crater.

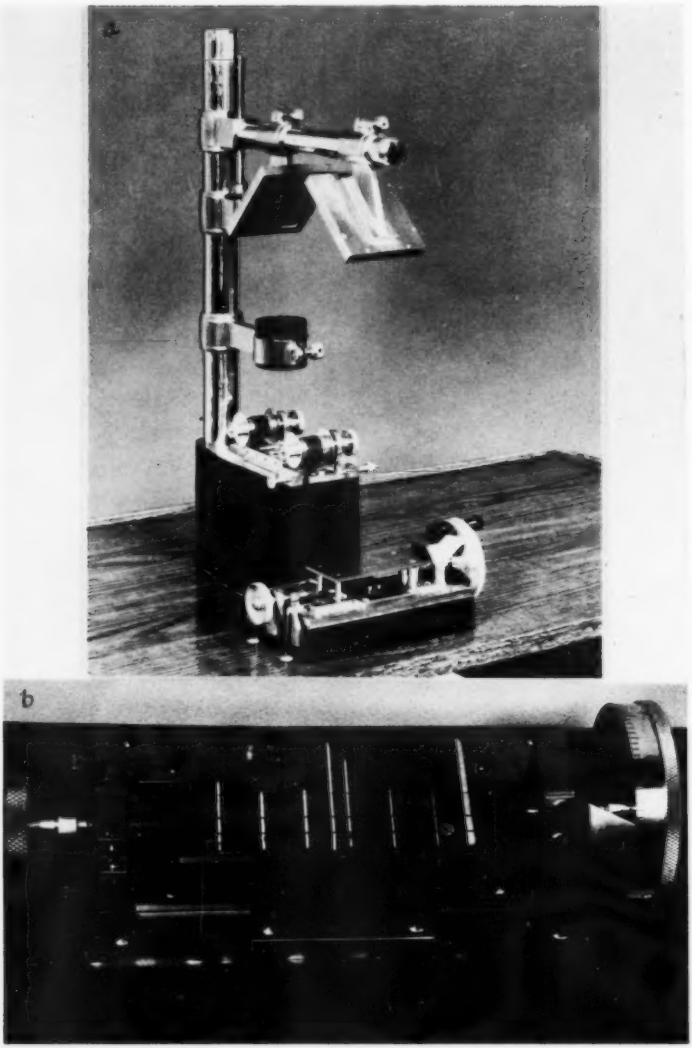
As the ages of the two craters mentioned here seem to be of the same order, it is reasonable to ascribe them to fragments from one single meteorite. If this is right we may also think that the other and less important craters in the region are also meteoric and produced on the same occasion. Further examination of these remarkable formations will surely lead to interesting results.

The craters are well preserved in spite of the intensive cultivation of the soil. Nobody in the region had the least suspicion of the origin of these holes and everyone was very astonished to learn that "Le Clot" was a marvel of nature. I suggest that the two areas in question should be laid out as national parks and put under real protection on the part of the French State. Really, "Le Clot" is one of the greatest known meteor craters in the world, fourth in diameter to the Chubb crater, the Arizona crater and the Wolf Creek crater. In one respect this crater surpasses all the others, it is placed in a very beautiful spot, the immediate surroundings are very attractive; looking towards the north we may admire the fine Black Mountains, towards the east and towards the west we see the pleasant slopes of the mountains towards the coastal plain, and if we direct our eyes towards the south we see the Mediterranean as a bright blue band on the horizon, across the fertile coastal land. Above our heads we see the deep blue sky of southern France. It is a most lovely place. We were loath to leave.

For an astronomer the visit to the Cabrerolles craters was a very interesting experience, and I should recommend every astronomer interested in these things to go to see them, they are the most easily accessible terrestrial "lunar-craters" of all.

Urania Observatory,
25 Dr. Olgas Vej.
Copenhagen. F. Denmark.
May 1951.

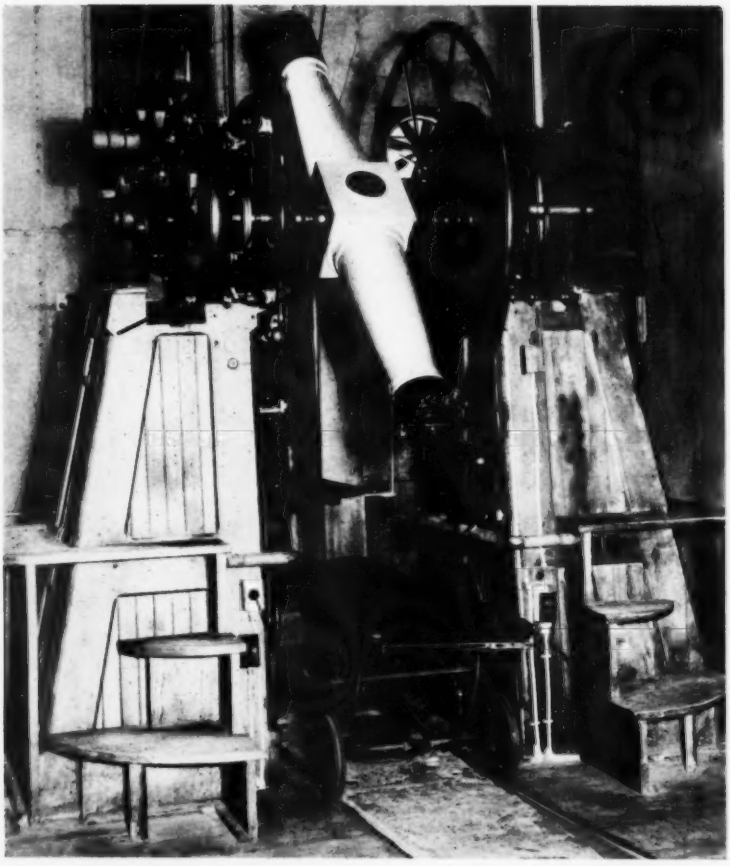
PLATE IX




(a) General view of projection measurement instrument. (b) Measuring plate and screws, showing fixed lines on plate and projected images of the fiducial wire in microscope and the division marks on the circle.

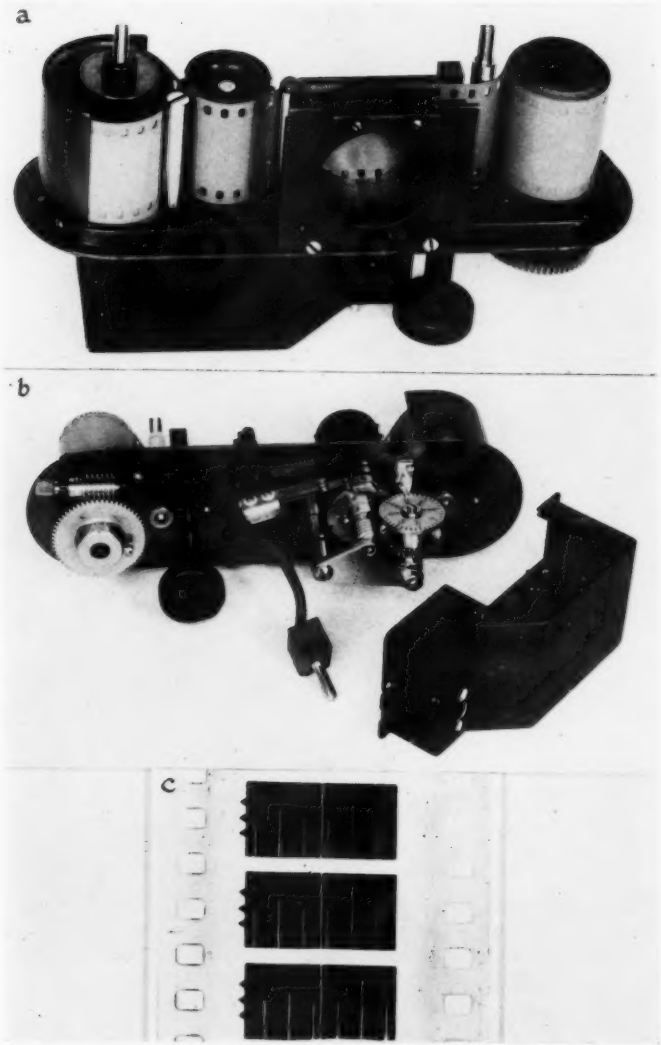
*Journal of the Royal Astronomical Society of Canada.*

PLATE VIII



General view of meridian circle; arrows indicate cameras.

PLATE VII




(a) Camera, showing film transport. (b) Camera, showing revolution counter and contact to control spacing. (c) Record of No. 3 Camera.

# PHOTOGRAPHIC REGISTRATION OF CIRCLE SETTINGS WITH THE OTTAWA MERIDIAN CIRCLE TELESCOPE

By W. S. McClenahan, E. G. Woolsey and R. W. Tanner

(With Plates VII to IX)

Abstract

The Ottawa meridian circle telescope has been modified to include cameras to photograph the division marks of the graduated circles. This has been done primarily to decrease the time required to observe a star and decrease the labour on the part of the observer; and secondly, to decrease errors of observation if possible. The design of the cameras is similar to that at present employed in the U.S. Naval Observatory at Washington, D.C. The cameras were developed to make use of the mountings and lenses of the microscopes which were formerly mounted on the east pier.

The project also included the development of a machine to measure the films. A projection machine has been built in which an image of the photographed scale division appears on a screen, measurement being effected by moving the screen on which are engraved suitable index marks. This instrument gives very little eyestrain and can be operated without the use of a dark room.

Although the accuracy of reading the circle divisions has been increased 100 per cent., it does not change appreciably the overall probable error of the star positions obtained by the observations. It has, however, increased the efficiency of the instrument by increasing the proportion of programme stars to total number of stars observed in a normal observing period.

## Introduction

The technique of observing with a meridian circle is laborious and exacting as compared with most types of astronomical observing, and it is difficult for a single observer to operate a conventional instrument of this type to the best advantage. Since it is necessary to obtain a certain number of reference or standard stars in each observing period, any change which speeds up the rate of taking observations increases the proportion of programme stars taken in a night's work, and improves the efficiency of both observing and computing. For this reason and for the purpose of improving the conditions of observing, a general review of procedures at the Dominion Observatory has been carried out.

One of the most important changes has been to modify the meridian circle instrument so that all the declination readings can

be recorded automatically. The declination reading consists of two parts, the off-set in setting the instrument to the nearest five-minute mark and the displacement of a star from a fixed wire in the telescope. The latter has always been recorded by a tape and type wheel. The former, by the introduction of the cameras, is now done photographically.

The cameras have been developed to make use of the mountings and lenses of the microscopes formerly mounted on the east pier. It has been found that this modification increases the efficiency of the instrument, particularly in winter, provides a better record of measurement and improves the resulting positions of the stars so taken.

## Description of Cameras

The design of the cameras is similar to that at present in use on the six-inch meridian circle at the U.S. Naval Observatory in Washington. Minor changes, however, have been made in mechanical parts and it is hoped that these will make operation more satisfactory for cold weather observing.

Drawings and photographs of the cameras in use at the Naval Observatory[1] were kindly supplied by C. B. Watts, Director of the Six-Inch Transit Circle Division. The original drawings for our own work were prepared by V. E. Hollinsworth of the Dominion Observatory staff, who also developed the method for operating the shutter. The cameras were built in the Dominion Observatory machine shop by L. P. Christensen, who contributed many ideas as the work progressed. The operation of the camera is proof of the excellent way in which they were constructed.

The cameras were developed to make use of the lenses and mounting system employed for the microscopes originally provided on the east pier. The microscopes on the west pier were retained for visual readings, if necessary. Due to the mountings, the focal length and size of the lenses and the position of the number marks on the circle, it was not possible to include a degree number in a frame which covers about thirty minutes of arc. However, since the circle is graduated in five-minute intervals and since the fifteen, thirty, forty-five minute and degree marks can be recognized by

[1]Publications of the U.S. Naval Observatory, vol. XVI, part 2, p. 354.

their length, there is no difficulty of identifying the sequence of photographs even though an occasional wrong setting was used or an odd photograph omitted.

Thirty-five millimetre, high contrast positive film is used and each picture is 5/8 inches by 5/16 inches with a space of 1/16 inch between exposures. Spacing is controlled and each camera holds sufficient film for two hundred exposures. The film is advanced by four Bodine 7.5-watt motors attached to the frame of the instrument. The drive is transferred from the motors by having a worm and gear attached permanently to the camera and connecting it to the motor by a four-inch flexible cable which fits over a square shaft. It has the advantage of eliminating a ratchet to control the film at the driving end, but necessitates independent electrical control for each motor. This latter is desirable here because the motors will not run at their rated speed in cold weather.

The shutters are fitted to the objective end of the tubes and are operated by 22-volt M Type Servo motors which have three phase windings. Only one phase is connected and the application of twenty-five volts d.c. pulls the armature through twenty degrees and opens the shutter. A light spring closes the shutter and retains it in the closed position. These motors were selected and adapted because they were ideally suited for the job and were available at a ridiculously low cost.

Illumination is provided by two 8-watt bulbs attached at the objective end of the tube and shielded to reflect their light on the division marks. The voltage is adjusted so that a 6-second exposure may be used.

The timing mechanism consists of 7 cams directly connected to an 8-watt one r.p.m. Telechron synchronous motor. In one revolution these cams control the motor itself, the illumination, the shutter and the motors for advancing the film.

The film magazine is made of brass and stainless steel and has an aluminum case, the whole weighing about $2\frac{1}{4}$ pounds.

Plate VIIa shows the camera with the cover removed. The film supply is mounted on a rotating cylinder and is prevented from unwinding by a covered guide. The cylinder rotates to prevent the film from binding should it be taken from near the centre of a roll. The film passes over a one-inch projector sprocket which

operates a revolution counter, details of which are shown on Plate VIIb. The revolution counter is set to zero when the cameras are loaded and provides a record of how much film has been used. The film next passes over the end of the camera tube which has a rectangular opening for the picture. A fixed reference line of brass wire is permanently fixed here as well as an identification mark for each camera. A polished steel plate, under pressure of two small springs, keeps the film against the end of the tube. The film is finally guided onto a spool which is operated by the motor. The advancement of the film after each exposure is kept constant by having each motor controlled by a cut-off switch operated by the projector sprocket which is shown on Plate VIIb.

Each camera is easily removed by releasing a single clamp, and a stop on the camera insures that it can be replaced in the proper position. The 4-inch flexible shaft is easily released and replaced and the electric circuit is completed with a jack on the side of the camera.

Plate VIIc shows a section of film taken with the camera No. 3. The long line in the centre of each picture is the fixed reference line from which measures are made. The cameras have been fixed to keep the distance between this mark and the nearest 5-minute mark to a little less than one minute. This is done to reduce the distance of measurement and to insure that the two lines are far enough apart to cause no confusion in measuring.

Plate VIII shows the complete instrument equipped with cameras and the illumination turned on.

## Performance of Cameras

The cameras were installed in June 1949, and have had two winters' trial. Winter provides a serious test for equipment as all observing is done well below freezing, at times 10 and 20 degrees below zero (Fahrenheit) and all mechanical and electrical equipment must be reliable even under these conditions. During this first winter the Telechron synchronous motors, which were originally purchased to drive the cameras, were found to be unsatisfactory. As a result they have been replaced by small electric motors geared down to 23 r.p.m. and thus have higher starting torque and more power. These motors worked very well down to about $-20°C$.

when the grease in the gearing mechanism became sufficiently congealed to prevent satisfactory operation. The lubricant has now been changed to overcome this difficulty. The Servo motors which operate the shutters have proved very satisfactory and so far there has never been a failure from this source.

## Instrument for Measurement of Films

A week's observing will produce several hundred frames of film on which the distance between a division mark and the fixed reference line is to be measured with an accuracy of about one micron, corresponding to one-tenth second on the circle. To avoid the eyestrain and fatigue of using a conventional measuring microscope, a projection instrument, following in general the design of Petrie and Girling of Victoria[2], has been built.

A general view is shown in Plate IXa. A hollow cast iron base is attached to a sturdy table before which the operator sits. The film is drawn by hand from the near spool over a rectangular opening in the base to the rear spool. Four rollers hold the film flat as it passes over the opening. Its orientation is controlled by the tangent screw seen on the top front of the base. The film is illuminated from below by the lamp and condensing system of a small commercial projector. These are fixed to the underside of the table and ventilated by a small fan.

A rigid vertical post supports an arm which holds the projection lens about 10 cm. above the film. The lens has a focal length of 10 cm. and is stopped down to f/6. Its distance from the film is adjusted by screwing it up or down in its mount. The second arm higher up the pillar carries two front surface aluminized mirrors of selected plate glass. This arm is moved vertically by a screw and gear mechanism, partly concealed by the rear mirror, to alter the second conjugate distance. The mirrors bring the image onto the rectangular plate immediately in front of the base, at a distance of about 60 cm. from the lens.

Plate IXb is a close-up view of the measuring plate and screws. The plate, 10 × 5 cm., is of stainless steel treated to obtain a semi-

[2]Journal of the Royal Astronomical Society of Canada, vol. XLII, p. 226, 1948. Dominion Astrophysical Observatory Contributions, 13.

matte surface. The black lines shown on the illustration are engraved and filled; the white lines are the projected image of six division marks and the reference line. The plate carriage may be moved either by the measuring screw whose divided head is seen on the right, or by the adjusting screw on the left. A weight under the table is attached by strings to the left end of the carriage to eliminate lost motion. The scale beside the carriage ways indicates revolutions of the measuring screws.

The whole table top is enclosed in a light wooden box whose sides and top keep strong direct illumination off the plate, while its open front admits enough light to read the divided head. The room is not darkened during measurement.

Measuring procedure is as follows: The film is drawn onto the far spool until the tops of the short division marks touch the central horizontal line on the plate. The lines of the image are made parallel to the vertical lines on the plate by the tangent screw. The magnification is varied by adjusting the height of the mirrors until 5 minutes corresponds to 7.5 revolutions, while focus is maintained by moving the lens. Provision for variable magnification in projection is necessary because the magnification afforded by the various cameras varies by one or two per cent. There is no sensible variation in scale from frame to frame, however, so that the instrument may be adjusted on the first frame of the film (division under the camera when the telescope is at nadir) and checked on the last frame, again the nadir division.

The measuring screw has a 2 mm. pitch, and the vertical lines on the plate are 15 mm. apart. Rough adjustment of the scale brings two division marks 5′ apart over two lines 15 mm. apart; fine adjustment brings the 5′ interval to equal $7.500 \pm 0.005$ revolutions. This tolerance allows the distance measured to vary by a quarter minute without introducing error of runs greater than $0''.01$. The distance division mark to reference line is in fact kept constant within $10''$ or so.

The magnification being adjusted and the measuring head set at zero, the plate is moved by the left-hand screw until the reference line falls on the central vertical line of the plate. The thickness of this line is so chosen as to leave a very thin thread of light from the image showing on either side of it. The setting is made on that

portion of the image comprised between the two lower horizontal lines. When the definition is good, settings can readily be repeated to a few thousandths of a revolution.

Next the plate is moved by the measuring screw until the nearby division mark is under the central line, and the reading recorded in units of 0.1 revolution. The first setting obviates the need for a subtraction, and it will be seen that the magnification and screw pitch have been chosen so that if the four camera readings of a single setting are added, the sum will be the desired mean of the four distances directly in seconds of arc.

During a couple of months, reading of the circle microscopes was continued while films were being taken, to serve as a check on the performance of the cameras and the measuring engine. In discussing these results it was found that the probable error of the mean of the four readings of a single setting with the cameras is 0″.12, while the corresponding figure for the circle microscopes is 0″.25. It was concluded further that no measurable distortion is introduced either by the camera or by the projection lenses; and that the time-saving use of both screws is unobjectionable in practice. No screw error is discernible over the small range involved in such differential measurements.

Some doubt arose over the stability of the cameras. In the course of the investigation, photographs were taken of the circle at the four settings 0°, 90°, 180° and 270°. From such a set of 16 readings the angles between the cameras as well as the angles between the division marks concerned may be obtained. It was noted that the angles between the cameras varied by amounts up to 10″ in the course of a few days. A further check was made by leaving the telescope clamped in one position, and taking photographs on several days over three- to six-hour periods at varying temperatures. A change in camera position of the order of 0″.2 per degree centigrade with change in temperature was evident, plus a random change, generally small, but on occasion reaching 0″.7.

R. M. Stewart[3] also found in 1911 that the microscope mountings were not sufficiently stable but considered that they were probably satisfactory for ordinary differential work. The microscopes are mounted not on a continuous ring but on separate arms extending

[3]Report of the Chief Astronomer, 1911, p. 309.

radially from the standard. In order to stiffen them, a cast iron ring was carefully fitted to the inner ends of the microscope carriers, thus connecting together each set of four microscopes. Unfortunately the construction of the standards rendered it impossible to extend the ring to an arc greater than 270°. As would be expected the cameras next the ends of this ring show the greatest movement with temperature and other causes. However, it is clear that the cameras are not less stable than the microscopes, and a continuation of the practice of taking nadir readings at intervals of an hour or two, interpolating where necessary, should hold errors from this source to a few tenths of a second.

Obtaining crisply defined images of all parts of the circles is impossible owing to the distortion of their form described by Stewart[4]. A compromise is obtained by focussing the cameras when the telescope is at setting 360° for circle A and 120° for circle B. A further difficulty is that the divisions themselves are too shallow to be filled; their edges are diffuse under high magnification, and care has to be taken with their illumination to secure suitable images for visual measurement. It is found that the variations in definition met with, although apparent to the measurer, lead to little loss of accuracy in setting with the projection machine.

A comprehensive test of the effect of errors from all sources consists in comparing the observed declination of stars with the values in the fundamental catalogue $FK_3$. For this purpose, on each of six nights a series of 25 $FK_3$ stars covering the whole observing range was taken using both cameras and microscopes. The results are summarized in Table I.

Each observation gives a residual, Observed − $FK_3$. The mean of these residuals for the night, columns 3 and 5, is the correction to the value of the latitude assumed in the reduction. After this quantity has been removed from the residuals, the mean error of a single observation, given in columns 4 and 6, may be calculated. It is seen that the cameras yield somewhat more uniform results, and that the overall error of observation has been slightly reduced.

The cameras alone have been used for observations made since July 1, 1950. The results obtained are slightly more uniform than

[4] *Ibid.*, 1910, p. 403.

TABLE I

OBSERVED − $FK_3$ DECLINATIONS

| Date 1950 | Observer | Microscopes | | Cameras | |
|---|---|---|---|---|---|
| | | $\Delta\varphi$ | $\sigma$ | $\Delta\varphi$ | $\sigma$ |
| May 2 | T | −1″.00 | 0″.72 | −0″.54 | 0″.62 |
| 15 | W | −0.05 | 0.68 | −0.17 | 0.63 |
| 19 | T | −0.32 | 0.48 | −0.26 | 0.65 |
| 30 | T | −0.14 | 0.78 | −0.20 | 0.70 |
| June 7 | W | −0.72 | 0.80 | −0.63 | 0.64 |
| 12 | W | −0.02 | 0.67 | −0.04 | 0.63 |
| | Mean | −0.38 | 0.69 | −0.31 | 0.64 |

in the past. The average rate of observing for a night has been increased from eight to eleven stars per hour; this marked improvement in the efficiency at the telescope more than compensates for the additional time required to measure the films. It is hoped eventually that this increased burden of office work will be alleviated through co-operation with the computing centre of the University of Toronto in getting much of the subsequent computation done on punched card machines.

# NOTES AND QUERIES

## Astronomischer Jahresbericht

The Editor has received for review vol. 46 of the *Astronomischer Jahresbericht*, the important German language compilation of abstracts of all astronomical literature, vol. 48 of which was reviewed in this volume of the Journal, p. 135. The presently received vol. 46 covers the remainder of the literature for the years 1943-46, the first part of this having been covered by vol. 45, issued previously.

J. F. H.

## The Velocity of Light

During the last two or three years the velocity of light has received considerable attention. One of the first determinations of its value, after the war, was made indirectly by Aslakson. He adapted the use of radar for measuring geodetic distances. An airplane flew across the line between the two ground stations, and as it flew it continuously determined its distance from each of the two stations. At the instant when the aircraft was on the straight line joining the two stations the sum of these two distances was a minimum and was equal to the actual distance between the stations. Corrections were made for the velocity of the radio waves in the air and the distances were reduced to sea level. About fifty lines of various lengths from about 70 to 370 miles were measured in this way. In comparing these distances with those determined by triangulation systematic differences were found. By simply reversing the procedure, assuming the distances to be the same but that the differences were due to the value of the velocity of the waves, Aslakson determined a new value for the velocity of light which is in agreement with other recent values.

An electronic counterpart of Fizeau's toothed wheel apparatus for measurement of the velocity of light has been devised by Bergstrand. A light source is caused to vary in intensity some 8 million times a second, and simultaneously the sensitivity of the receiving photoelectric cell is varied. At certain distances between photocell

and source, the photocell gives a maximum response, when the light-pulses are received in phase with moments of high sensitivity of the cell; as the distance between light and cell is increased the light-pulses are received while the cell is less sensitive, until a point is reached where substantially no photo-current is received. Accurate measurement of the distances (which are the size of a large room) and the high accuracy of electronic time measurements, allow a very accurate determination of the velocity of light.

Since radio waves are also electro-magnetic waves, like light, but of considerably longer wave-length, it is possible to measure their velocity of propagation very conveniently, as has been done by Essen in England and Bol in California. Successive reflections of radio waves within a small, hollow, silver-plated cylinder several inches long, will set up standing waves, if the frequency of the radio waves is correctly adjusted to the dimensions of the cylinder. The correct frequency can be very accurately determined by radio methods, and the corresponding wave-length is a simple multiple of the length of the cylinder. This length is determined by interferometric measures, accurate to better than one part in a million. The velocity is then obtained by multiplying the frequency of the radio wave by the wave-length. Those who remember their high school physics will remember an analogous experiment in determining the velocity of sound in air by using a pipe of variable length and seeking the resonant length.

In the May-June 1950 issue of this JOURNAL an account was given by McKinley of his determination of the velocity of light using quartz crystals. Although this work was done in 1937-38, the technique developed would yield a result of comparable accuracy with current values.

The recent values of the velocity of light in km. per sec. follow:

| | | |
|---|---|---|
| Aslakson | 299792 $\pm$ 2.4 | *Nature*, vol. 164, p. 711, 1949. |
| Bergstrand | 299792.7 $\pm$ 0.25 | *Nature*, vol. 165, p. 405, 1950. |
| Bol | 299789.3 $\pm$ 0.4 | *Phys. Rev.*, vol. 80, p. 298, 1950. |
| Essen | 299792.5 $\pm$ 3 | *Proc. Roy. Soc.*, ser. A, vol. 204, p. 260, 1950. |

For comparison, the currently accepted value of the velocity of light as quoted in the OBSERVER'S HANDBOOK is 299,774 km. per sec.

R. E. W.

### Galactic Distances with the 200-inch

The first significant results of extra-galactic research obtained with the 200-inch telescope on Palomar Mountain were reported at the June meeting of the Astronomical Society of the Pacific by Dr. Milton Humason. For over twenty years Dr. Edwin Hubble and Dr. Humason have been working on the problem of the radial velocities of extra-galactic nebulae. These objects are extremely faint, and the increased light-gathering power of the 200-inch telescope over the 100-inch, cut down exposure times from twenty-four hours to about six hours. Velocities were reported of six nebulae which are members of distant extra-galactic clusters. The most distant of these, in Hydra, is too faint to be observed spectroscopically with any other instrument. It is fainter than 19th magnitude and has a red-shift corresponding to a velocity of 61,000 km. per sec., one-fifth the velocity of light. This is by far the largest radial velocity ever measured. The following table lists the largest velocity measured in km. per sec., the object observed and the year (A.S.P. Leaflet no. 267).

| | | |
|---|---|---|
| 1922 | 1,800 | N.G.C. 584 |
| 1932 | 20,000 | Leo cluster |
| 1942 | 40,000 | Boötis cluster |
| 1951 | 61,000 | Hydra cluster |

Hubble and Humason found that the velocity of recession is proportional to the distance of the external galaxy. With these most recent observations the relationship has been extended fifty per cent. to a distance of about 360 million light-years. It is expected to be able to extend it farther, to distances of about 500 million light-years.

R. J. N.

## REVIEW OF PUBLICATIONS

*Ninth Astronomer Royal: the Life of Frank Watson Dyson*, by Margaret Wilson. With portraits and other illustrations. Pages 294, 6 × 9 inches. Cambridge: W. Heffer & Sons. 25*s.*, 1951.

The late Astronomer Royal Dyson had a family of eight children—four girls, two boys, and two more girls, all of whom grew to maturity. The author of this book is number four in this noble succession, but she acknowledges great help from her oldest sister.

Of the previous Astronomers Royal there have been sketches of their achievements but not a real biography of any one of them. Like the Poet Laureate the Astronomer Royal is a national figure and his work should have some interest for the people of the nation.

The author states that she is not a scientist and has too high a regard for science to dabble in what she does not understand. But throughout the book when referring to astronomical questions she shows a full appreciation of the matter under consideration and her precision of statement and choice of language make its significance clear to any intelligent person.

In this book every step that Frank Dyson took is traced and the account of his busy and useful life admirably presented. There are twenty-six chapters and the reader may start at the beginning or even in the middle of any one of them and be charmed with the narrative, it is so full of human interest.

Frank Watson Dyson was born on Jan. 8, 1868, at Measham in Derbyshire, the eldest of the seven children of Watson Dyson, a Baptist minister, and Fanny Dodwell, an earnest worker in the same denomination. There was a tradition of farming in the Dyson family but an even stronger one of nonconformity.

A later scene of the minister's labours was Halifax, in the West Riding of Yorkshire where he spent ten active years, beginning in February 1878. Frank attended for four years the Heath Grammar School which had been founded in 1585 for instruction in the classics. Frank had given evidence of superior mathematical ability, and his father was advised to send the boy to the Bradford Grammar School which had attained a wide reputation under William Keeling. He had

been its Head since 1871 and was ruthless in his methods. He went after the clever boys—and got them. The father wrote to Keeling, who replied, "No vacancy".

Soon after this, at the end of 1881, Frank won a great success in the Cambridge Local Examinations. He obtained honours in mathematics and indeed took first place in all England that year. Keeling's attitude swiftly changed. He wrote at once to Mr. Dyson offering Frank a Governors' Scholarship. In April 1882 Frank entered the school, all his fees being paid. He still lived in Halifax and went each day by train to Bradford which was seven miles away to the north-east.

Dyson stayed four years at Bradford, leaving in July 1886. His ability together with hard work had won him scholarships every year, and besides these he won an open scholarship at Trinity College, Cambridge. To supplement this the Bradford school gave him the Brown scholarship and the two together covered most of his expenses at Cambridge.

In June 1889 Dyson obtained his degree, gaining first class honours in mathematics, with the standing of Second Wrangler, the First Wrangler being G. T. Walker. In 1891 he won a Fellowship and was First Smith's Prizeman. In 1892 he was awarded the valuable Isaac Newton Scholarship. In this way he was in easy circumstances and was able to stay at Cambridge coaching, lecturing and carrying on research, until a good opening should appear. It came at the end of 1893, when Dyson was chosen Chief Assistant at the Royal Observatory in succession to H. H. Turner who had been appointed Savilian Professor at Oxford. Dyson's official appointment was March 1, 1894.

He was now definitely started on his life-work. After eleven years as Chief Assistant he was appointed Astronomer Royal for Scotland in 1905, and in 1910 he was made Astronomer Royal and moved back to Greenwich. Here he remained for 23 years when he was retired.

He was successful in whatever fell to him to undertake. He loved to travel, and in 1935 he came as a special guest to the official opening of the David Dunlap Observatory. His death occurred on May 25, 1939, on his way home from Australia and he was buried at sea in lat. 29° 55′ S., long. 67° 05′ E. (in the Indian Ocean).

It would seem that all the facts of the life of the Ninth Astronomer

Royal are given in this remarkable biography, and one can well believe that it was inspired by the author's "admiration and affection" for him.

C. A. C.

*Astronomical Dictionary, the Zodiac and the Constellations:* Arabic star-names, their meaning, transliteration and pronunciation, by Mansur Hanna Jurdak, M.A. Beirut, Lebanon: American Mission Press, 1950.

The author of this 350-page scholarly book is Professor Emeritus of Mathematics at the (reputable) American University of Beirut. In his preface he states that it is published in an endeavour to introduce both Arabic and English readers to the real form of Arabic star names and astronomical terms in the Arabic language. The work was begun in 1900-01 when the author was a student under R. S. Dugan at Beirut and has been continued by him ever since. He was Professor of Astronomy and Director of the Observatory 1914-19.

C. A. C.

*Science French Course,* by C. W. Paget Moffatt, revised by Noel Corcoran. Fourth edition. Pages 332, 4¾ × 7¼ inches. Chemical Publishing Co. Inc., New York, 1951. Price $4.75.

The preface of this book states that it is designed to enable students without any previous knowledge of the language to read French scientific and technical literature. In this country a student is more likely to need to brush up on his French than to learn it from scratch. For brushing up, the book is excellent, providing the student remembers enough English grammar to understand the short pithy rules and explanations that are given. But for learning from scratch, the book suffers from a lack of French passages with their English translations alongside. Of this nature there are only a few short phrases and sentences which illustrate each specific point. There are indeed, numerous French scientific passages for practice purposes, but these are accompanied neither by translations nor by references to the text. A beginning student might well get the frustrated feeling that he could not read them until he understood the text sufficiently, and that if

he understood the text sufficiently he would derive little benefit from reading them. On the other hand, a student who is reviewing his French will find the rules and explanations well arranged, the practice passages well chosen (there are no astronomical passages, however!), and the vocabulary excellent.

J. F. H.

*Viscosity and Plasticity* by E. N. da C. Andrade. Pages 84, 5¼ × 8½ inches, N.Y., Chemical Publishing Co. $2.25, 1951.

This book contains in written form three lectures delivered by Prof. Andrade before the London section of the Oil and Colour Chemist's Association. Intended to provide technicians with a survey of what is known of the theoretical background of special problems of viscous and plastic materials, it preserves the easy style of the spoken word. The discussion covers many fascinating problems in the behaviour of matter in the borderline cases where the distinctions between the states are confounded—the same material can simultaneously exhibit the properties of an elastic solid, and of a liquid. The book is nicely produced.

R. L. B.

# OUT OF OLD BOOKS

By Helen Sawyer Hogg

## Pieter Dircksz Keijser, Delineator of the Southern Constellations

A year ago in this Journal (Sept.-Oct. 1950) we published a summary of the origin of the eighty-eight constellations accepted today. The account that we reprinted from Chambers' "A Handbook of Descriptive Astronomy" attributed the naming of the southern constellations to Bayer. Actually Bayer's material for the southern stars came from early Dutch navigators, and the historical problem has been to identify which one of several was really responsible for first charting the southern sky.

For several centuries the credit was given to Frederick de Houtman who published in 1603 a "Catalogue of the Southern Stars" which he said was made from his own observations. In 1917, however, E. B. Knobel expressed grave doubt concerning de Houtman's claim. In a paper entitled "On Frederick de Houtman's Catalogue of Southern Stars, and the Origin of the Southern Constellations" (*Monthly Notices*, vol. 77, p. 414) Knobel reached the conclusion that, contrary to his own word, Frederick de Houtman was not the first to observe the positions of the southern stars, but rather that Pieter Dircksz Keijser was actually the first observer. Any proofs that Knobel could find for this assumption were of a somewhat negative character,—indications, rather than proofs.

Recently a decisive paper has been received from Dr. J. W. Stein, S.J., of the Vatican Observatory. Following the lead given by Knobel, Dr. Stein has done a clever bit of historical research and has proved, once and for all, that Pieter Dircksz Keijser first mapped the southern stars.

We quote from Knobel's account of the first study of the stars around the south celestial pole.

> The origin of the constellations surrounding the South Pole is involved in much obscurity. They have all been attributed to various Dutch, Spanish, Portuguese, and Italian navigators, but the original records of the observation and formation of the different constellations appear to be lost.
>
> The earliest existing map of the southern heavens is found in the map of the world made by Peter Plancius in 1594, entitled "Orbis terrarum typus de

integro multis in locis emendatus Petro Plancio, 1594", given by Linschoten (*Navigatio ac Itinerarium*, 1599). In this map, besides the Ptolemy constellations, are shown Columba (the stars of which are in Ptolemy), Crux as a separate constellation (also in Ptolemy), Eridanus continued from Ptolemy's 34th star to α Eridani, Triangulum Australe, and a large constellation in the figure of a man called Polophilax, consisting of seven stars which I have not identified. The two Nubeculae are shown, but nothing else. It is tolerably clear that at this date no other southern constellations were known. Thomas Hood (*Celestial Map*, 1590) states that no more stars than those in Ptolemy have been observed.

The earliest publications containing the constellations surrounding the South Pole as we know them, are in Frederick de Houtman's *Catalogue of Stars*, Bayer's *Uranometria*, and Blaeu's *Celestial Globe*, which all appeared in the same year, 1603.

In the 49th map of Bayer's *Uranometria*, published at Augsburg, 1603 September, are shown the constellations Phoenix, Hydrus, Tucana, Grus, Indus, Pavo, Apus, Triangulum Australe, Musca, Chamaeleon, Volans, and Doradus. His map of Eridanus shows the continuation beyond the last of Ptolemy's stars to α Eridani; it also gives some stars in Phoenix and Doradus; that of Canis Major gives Columba, "recentioribus Columba"; Argo shows some stars in Volans; Centaurus includes Crux as a figure, and Triangulum Australe; Ara shows some stars in Triangulum, Grus, and Pavo; Piscis Austrinus includes stars in Grus. Bayer states that these constellations were observed partly by Amerigo Vespucci, partly by Andrea Corsali and Pedro de Medina, but their places were determined by that "most learned" seaman Petrus Theodorus.

Blaeu in his *Celestial Globe*, published in 1603, ascribes all the above constellations to Frederick de Houtman. Merula (*Cosmographia Generalis*, 1605) attributes all the observations of the "longitudes, latitudes, declinations, etc.," of the stars in question to Petrus Theodorus.

Knobel gives other references to the subject in early seventeenth century literature, concluding that the claim to the first charting of the southern constellations rests between Frederick de Houtman and Petrus Theodorus. But just who was Petrus Theodorus, and is it possible to decide which of the two men actually made the first positional measures of the southern stars? Knobel states:

Much uncertainty has existed as to the identity of Petrus Theodorus, and of the extent of his contributions to our knowledge of the southern constellations. His name is given in Latin as Petrus Theodorus F. Embdanus, and in German, Peter Theodors Sohn; but in 1825 Moll, in his work on the early naval expeditions of the Dutch, identified him as Pieter Dircksz, or (as the final z stands for zoon) as Pieter Dircksz oon; but he was unable to find any information about him, and he inquires whether this is the same person mentioned by Blaeu as Frederick de Houtman. I find in a Dutch dictionary that the English equivalent of the Dutch name Dirk is "Theodoric"; hence, in translating the Dutch name Pieter Dircksz(oon) into Latin, it became Petrus Theodorus

F(ilius). From Olbers (*Schumacher Jahrbuch für* 1840) and De Jonge (*De opkomst van het Nederlandsch Gezag in Oost-Indie*, 1862) we learn that his full name was Pieter Dircksz Keyzer. This man was instructed in mathematics and astronomy by Petrus Plancius, who was celebrated as a geographer and for his knowledge of astronomy and nautical matters, and who was one of the principal promoters of the Dutch expeditions to the Indies.

The first expedition of the Dutch to the East Indies sailed from the Texel 1595 April 2. It consisted of four ships, the second of which, the *Hollandia*, commanded by Jan Dignumz, carried Pieter Dircksz Keyzer as chief pilot and head of the steersmen, and Frederick de Houtman as sub-commissioner in the mercantile part of the expedition, with whom we here first become acquainted. From the journals and log of this ship and De Jonge we learn that the *Hollandia* arrived at Madagascar about 1595 September 3, and stayed there some time. It was here that Pieter Dircksz Keyzer "sought comfort in science, and enriched his knowledge of astronomy by improving the position of old and the observation of new constellations." It must have been at this time that Frederick de Houtman prepared that portion of his vocabulary, referred to below, which deals with the dialect of Madagascar. The ship went on to the Malay Archipelago, and though it is difficult to be certain about dates, it apparently anchored at Achin in Sumatra about 1596 June 5. After three months there it went on to the Straits of Sunda, where on 1596 September 13 Pieter Dircksz Keyzer died. Frederick de Houtman returned in the *Hollandia*, arriving in Holland about 1597 August 10. In the following year, on 1598 March 15, he went out again with a fleet, in command of the ship *De Leeuwin*. The chief pilot of the fleet was John Davis (not to be confounded with John Davis of Dartmouth, the inventor of the Davis Quadrant), and from Davis's journal we learn that the fleet arrived at Achin in Sumatra 1599 June 21. Tiele (*Mémoires sur les voyages Néerlandais*) says that Frederick de Houtman was taken prisoner by the King of Achin in 1598, and kept so for twenty-six months. This can hardly be correct, as he did not arrive there till sometime in 1599. He was, however, for a long time prisoner, and only escaped on 1600 December 31, when he went on board a ship commanded by van Caerden, which was then at Achin. He then returned to Holland. To conclude his career, in 1603 he went out on another voyage as mercantile commissioner, and two years after became governor of Amboyna. I have thus endeavoured to account for all Frederick de Houtman's time, which bears upon the authenticity of his *Catalogue of Stars*.

In 1603 Frederick de Houtman published at Amsterdam a Malay and Madagascan vocabulary, entitled *Spraeckende woordboeck Inde Maleysche ende Madagaskarche Talen met vele Arabische ende Turksche woorden*. At the end of this work he gives a catalogue of southern stars, the title-page of which is thus translated: "Here follow several fixed stars (observed), with efficient instruments, by Frederick de Houtman, in the island of Sumatra, (their positions) corrected and their numbers increased. For the use and service of those who navigate south of the equinoctial line, and also for all amateurs and those who have occasion for the best. . . ." In a dedicatory letter to the vocabulary Houtman says: "There will be found at the end the declinations of several

fixed stars in the region of the South Pole which I had observed on my first voyage, and which on my second voyage I revised and corrected with more care and brought up to the number of 300, as may be seen on the Celestial Globe published by William Jansen (Blaeu)".

This work is extremely rare; every effort that I have made for many years to obtain a copy in Germany, France, Italy, and elsewhere, and by advertising, has failed. Four copies are certainly known, at the British Museum, the Bodleian, the Bibliothèque Nationale, and at Leiden. Thanks, however, to the enterprise of Professor Turner, he has had the copy in the Bodleian photographed, and thus this interesting catalogue—the first catalogue of southern stars ever made—is available.

The catalogue consists of the right ascensions, declinations, and magnitudes of 303 stars, of which 107 stars are found in Ptolemy, leaving 196 newly discovered. The right ascensions are too rough to allow of identification, but by plotting the whole catalogue in a map, and comparing with the maps of the *Uranometria Argentina*, it has been easy to identify nearly every star. . . .

Was this catalogue made by Frederick de Houtman at Sumatra on the occasions of his two voyages there, as he states?

On his first voyage, then twenty-four years of age, he was in a purely commercial capacity, and there is no record of his being an astronomer or of his having any mathematical ability. Most of his time at Sumatra on both occasions he was at Achin, which is in latitude 5° 34′ North; and, as we infer from the ship's journals of the first voyage, he was there on that occasion only some three or four months. The journal of his second voyage is not published, but we have enough information to infer that while at Achin, he had but a limited time at his disposal, as he was early taken prisoner by the king and kept in confinement for many months; and unless we assume that during his imprisonment he was able to make astronomical observations, there would have been no sufficient time for an inexperienced man to make the catalogue in question. How did he determine the right ascensions, rough as they are? In his catalogue he gives the positions of twenty-four stars, 7 of the 4th, 15 of the 5th, and 2 of the 6th magnitude, whose zenith distances at Achin ranged from 80° to 89° 15′; *obviously he could not have seen them at all.* . . .

Pieter Dircksz Keyzer, who was versed in mathematics and astronomy, and was held in high estimation by the Dutch East India Company, would have a favourable opportunity during the long stay of the *Hollandia* at Madagascar, from 1595 September to April or May of 1596, to make observations and to chart the new constellations. As Merula says: "sedens ibi in corbe, vel ut vocant nonnulli, galea." In that latitude he could quite well observe 5th and 6th magnitude stars near the South Pole. For the right ascensions we may surmise that Plancius would furnish him with some of Tycho Brahe's observations, from which they might be roughly derived; certainly there was no other material available for the purpose. I have failed to find any information as to relations between Tycho Brahe and Plancius.

Frederick de Houtman was in Pieter Dircksz's company all the time, but

as commissioner he would be engaged in the development of trade, and, moreover, he was then collecting materials for his Malay and Madagascan vocabulary. Though all the evidence is circumstantial, the following inferences are irresistible: that the whole catalogue and the formation of the new twelve constellations must be attributed to Pieter Dircksz Keyzer, and not in any way to Frederick de Houtman: that the catalogue was sent back by the *Hollandia*, and after the return of that ship on 1597 August 10 it would go to Plancius, who probably communicated it to Bayer: and that Frederick de Houtman obtained an imperfect copy of it which, as Pieter Dircksz was dead, he published as his own work in the above-mentioned vocabulary.

Knobel in concluding his article reprinted eleven pages of the star catalogue as given by Frederick de Houtman in his "Malay and Madagascar Vocabulary." But it has remained for Dr. J. W. Stein, S.J., to find the proof of Knobel's surmise that Pieter Dircksz Keijser was the originator of the southern constellations, and publish the evidence in his fascinating paper, "The Celestial Globe of Jodocus Hondius of 1600," in the Miscellanea Astronomica of the Vatican Observatory, vol. III, No. 101, 1950, which shows three photographs of the globe. Dr. Stein states:

Knobel knew of no document antedating 1603 which made mention of the new constellations. In particular, Knobel was unaware of the existence of the celestial globe which Hondius produced in the year 1600, and which even by itself is quite sufficient to decide the question of priority. A description of this precious globe, one specimen of which is in the possession of the Nautical Museum of Amsterdam, was given by the present author (at the request of the Director of the Museum, Mr. W. Voorbeijtel Cannenburg) in the 13th Annual Report of the Museum. (1929).

The Hondius globe is very remarkable, since it is the first one on which the new southern constellations were depicted. The assigned names of the constellations (clearly painted in vivid colours) are: Phoenix, Watersnake (Hydrus), Goldfish (Dorado), Fly (Musca), Flying Fish (Volans), Chameleon, Southern Triangle (Triangulum Australe), Bird of Paradise (Apus), Peacock (Pavo), Indian (Indus), Heron (Grus), Toucan (Tucana). In addition to a representation of Tycho Brahe, the globe bears two inscriptions.

The first inscription contains the maker's dedication of the globe to the Academies of Leiden and Franeker: (Translation from the Latin). "To the Academies of Leiden and Franeker, most illustrious luminaries of Belgium and sources of wisdom, learning and true piety, Jodocus Hondius in the year 1600 with the greatest of pleasure dedicates and consecrates these globes engraved by his own hand for the advancement of the mathematical arts." From the use of the plural, "globos", we surmise that a terrestrial globe was constructed at the same time, as was usually the case.

The second inscription mentions the names of Tycho Brahe who observed

the northern constellations, and of Pieter Dircksz, who observed the southern constellations. . . . Translation: "A celestial globe on which are most accurately marked all of the fixed stars which the nobleman Tycho Brahe observed so industriously and carefully, as well as the southern circumpolar stars which were observed by the most learned navigator, Peter Son of Theodore, student of mathematics."

Jodocus Hondius was born in 1567 at Wacken in West Flanders. Even in his early youth he revealed unusual talent for drawing and engraving, and so he was apprenticed by his father Oliver to an engraver in Antwerp. About 1585 he went to England, where he devoted his talents to the service of the geographers, Richard Hakluyt and Edward Wright. In 1592 he established himself at Amsterdam, and became a specialist in publishing geographical charts and constructing celestial and terrestrial globes. As far as we know, his first celestial globe was dated 1592. Of his next globe, built in 1600, only two certainly identified specimens remain; one is in the Nautical Museum of Amsterdam and the other is in the collection of the Henry E. Huntington Library in Pasadena, California. Both of these globes are illustrated in the previously mentioned Annual Report of 1929.

Dr. Stein corroborates and repeats the conclusions previously reached by Knobel, that Keijser made the observations during his stay at Madagascar:

The *Hollandia* arrived at Madagascar on September 3, 1595, and remained anchored there until April or May, 1596. In the meantime both Keijser and Houtman transferred to the ship *Mauritius*. It was during this long stay at Madagascar that Keijser sought comfort in science by improving his knowledge of the positions of the old constellations and by securing his observations of the new ones—"sedens ibi in corbe, sitting in the crow's nest", as Professor Merula of Leiden tells us in his *Cosmographia Generalis* (1605). About June 5, 1596, the fleet arrived at Atchin, Sumatra, and after three months they anchored at Bantam in the Straits of Sunda, which lie between Java and Sumatra. There Keijser died on September 13th; "mortuus est in coelo lustrando," while scanning the heavens, as Merula says. Houtman returned to Holland on August 10, 1597. The ship's journals of Keijser were turned over to Plancius, who then communicated the observed star positions to Merula, as attested by the latter. Hondius also must have had access to a copy, which enabled him to delineate the new constellations on his globe of the year 1600. . . .

That Houtman has misappropriated the honour of having *first* observed and delineated the southern constellations is definitely proved by the inscription on the globe of Hondius of the year 1600, in confirmation of the statement of Professor Merula, who received the original observations of Keijser directly from Plancius. The honor of having first measured the positions of the southern circumpolar stars and of having formed from them twelve new constellations is due exclusively to Pieter Dircksz Keijser.

# MEETINGS OF THE SOCIETY

## AT TORONTO

*March 20, 1951.*—The meeting was held in McLennan Physics Laboratory, the Chairman being Mr. F. L. Troyer, President.

Two new members were elected to the Society. These were:

Mr. William Mitchell, 60 Frizzell Ave., Toronto.

Mr. Gordon M. Craig, Milliken P.O., Ontario.

Mr. F. K. Dalton spoke on, "Those Mysterious Meteorites".

Mr. Dalton gave general information on meteorites and their theories of origin, before describing the interesting work which he has been doing on microhardness testing of meteorites, and for which he received the Chant Medal this year.

The talk was a most interesting one and demonstrated the fact our own amateurs can contribute substantially to the science of astronomy. The details of this microhardness testing are given in papers in this JOURNAL.

W. R. HOSSACK, *Recorder.*

*April 3, 1951.*—The meeting was held in McLennan Physics Laboratory, the Chairman being Mr. F. L. Troyer, President.

The President introduced the speaker, Professor T. F. McIlwraith, head of the Department of Anthropology, University of Toronto. The title of Professor McIlwraith's address was "Star Lore of the North American Indians".

The speaker told of the importance of astronomy, as a science and as a spiritual influence in the lives of the North American Indians. The sun rituals of the early Mexican tribes were described, as well as some of the interesting star legends characteristic of the northern tribes. Emphasis was laid upon the fact that the interests of the people are shown in their legends.

The talk was a delightful one and was enthusiastically received by the Centre.

Mr. Horning thanked the speaker, and the meeting adjourned.

B. GUNN, *Acting Recorder.*

## AT MONTREAL

*October 26, 1950.*—The 32nd Annual Meeting was held at Macdonald Physics Building, McGill University, on Thursday, October 26, 1950, at 8.15 p.m. The President, Mr. J. W. Duffie, was in the Chair.

It was moved by Mr. R. Venor, seconded by Mr. Birtles and carried that the following be admitted to membership: Miss Mary Cream, Messrs. Thomas Ard, H. Mothersol, W. E. Jeynes, L. W. Anderson, C. S. Glassco, F. R. Pattison, Jos. Pintar, Gerald D. Seaboyer, Ernest Snape, Robert Gardner, D. M. Towler.

The reports of the year's activities were then presented by the Treasurer, the Director of Observations, Librarian and Secretary. Adoption of these reports was moved by Mr. G. Harper Hall, seconded by Mr. D. Zackon and carried. The election of Officers, and members of the Council followed. The retiring President then installed the newly elected President, Miss I. K. Williamson. It was announced that in addition to the regular lectures and observation meetings, plans were being made for a six-lecture course in telescope making, conducted by Mr. R. Venor. The class would begin as soon as suitable accommodation could be found for the group.

The Chairman acknowledged with thanks the following donations to the Centre's library:

"Variable Stars", Gaposchkin & Gaposchkin. Presented by Mr. J. W. Duffie
"The Nature of the Universe", Hoyle. Presented by Mr. C. L. Reeve
"British Nautical Almanac", 1951. Presented by Dr. D. E. Douglas

The "Gladys Whipple" telescope was then brought in and formally accepted by the Centre. This instrument was made by Mr. A. V. Whipple for his wife, a very active member of the Centre, and presented to the Centre in her memory. In accepting it, the President paid tribute to Mrs. Whipple's love for astronomy, and to the happy memories cherished by those who knew her. The telescope has numerous unique features which won for it the award at the Telescope Makers' Convention at Stellafane, in Springfield, Vt., in August 1948.

The retiring President then gave an address entitled "Science, and People Like Us" in which he stressed the cultural value of the study of the universe around us, and of the value of cultivating interests in the advancement of knowledge, citing the need for this in the years following retirement from the more pressing activities of business life. The non-professional can do valuable work in his chosen field, and not all the advance in knowledge stems from the professional ranks. Independence of thought, and freedom of enquiry must be upheld and kept free from the fate which has overtaken the search for truth in certain quarters, and permit the individual to pass judgment upon, and draw his own conclusions concerning supposedly scientific material presented for his acceptance.

On conclusion of this address, Mr. F. DeKinder suggested that it be reproduced and made available to the members. Mr. Ross Stevenson then moved a vote of thanks to the speaker not only for his fine address but for the time and thought he had contributed to the Centre during his term of office as President.

*November 9, 1950.*—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, November 9, 1950, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 140 members and friends were present.

On motion of Mr. F. DeKinder, seconded by Mr. R. Venor the following were admitted to membership of the Centre: Messrs. Walter Mitchell, Louis Petyi, C. Wesley Murray, A. L. Burran.

Further information was asked relative to the bright meteor of November 2nd. Dr. Millman, Ottawa, has requested more reports from anyone who observed it.

As a means of making the Handbook more useful to members, short Handbook talks will precede lectures. The first of these talks was given by Mr. C. M. Good, on the "Symbols for the Planets".

The feature of the evening, a series of moving pictures followed, the films shown were: "What is Science?", "Hermits of the Sky", "The Solar Family", "The Nature of Colour". The thanks of the Centre for these films was expressed by the President to the Film Chairman, Young Men's Section, Board of Trade.

*November 23, 1950.*—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, November 23, 1950, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 91 members and friends were present.

The following were admitted to membership of the Centre: Messrs. Frank Varley, F. J. Pearce, Alexis Baranyi.

Announcements of observation meetings and other activities were made. It was reported that the Telescope Making Group had commenced, under the leadership of Mr. R. Venor, and the thanks of the Centre were extended to Mr. and Mrs. Eugene Charters for the use of their home for this activity. The second of the Handbook talks was given by Mr. H. F. Hall, on "Conjunctions, Oppositions, and Quadratures".

The speaker of the evening, Mr. A. E. Covington of the National Research Council, spoke on "Reception of Radio Noises from Sun, Moon and Galaxy". The lecture was illustrated by slides showing the apparatus used, graphs and diagrams. Dr. Douglas expressed the appreciation of the Centre to Mr. Covington.

*December 7, 1950.*—A meeting of the Montreal Centre of the Royal Astronomical Society of Canada was held in the Physics Building, McGill University, on Thursday evening, December 7, 1950, the President, Miss I. K. Williamson, in the Chair. 63 members were present. The President stated that the observation meetings would be held each Saturday evening throughout the holidays.

Mr. Good, the Librarian, then made several brief announcements: 1. That it had not been possible at this time to obtain the copies of the "Handbook of the Heavens". 2. That he acknowledged with thanks from the Centre the gift of the book "The Majestic Universe" donated by Mr. Leeson. 3. That Miss Ross had kindly donated to the Centre three pictures, Galileo, Herschel, and Newton which he accepted with thanks. 4. That a number of bound copies of the Journal were available if anyone wanted to purchase them.

A letter from Dr. P. M. Millman was read in which he thanked the members of the Centre for the reports on the November 2nd fireball and stated he would write us when final results were obtained.

The President explained briefly how the Centre was financed, that the fees

collected were sent to Headquarters in Toronto who returned in the following year a $1.00 grant for each member. It was mentioned that if any member would like to give a donation with their fees it would help the council of our Centre in maintaining and enlarging our programme and activities.

Mrs. J. Wright then gave a brief Handbook talk on "The Greek Alphabet" and how the letters were used to designate the stars in the constellations.

The programme of the evening consisted of a symposium of three brief talks. Mr. H. F. Hall in discussing the "Asteroids, the pygmies of the skies" told the story of the discovery of these bodies, and of their names, distances and orbits. He read portions of a book printed in 1826 which the members found very interesting.

Mr. F. DeKinder, speaking on the subject, "An amateur looks at the Sun", described the system of observing sun-spots, studying the disk, and counting groups and spots in each group. He showed how the spots are observed by direct vision or by projection and explained how the monthly report is completed.

Mr. F. Morgan then discussed "New Theories of the Origin of the Solar System" and mentioned four theories considered since 1940. 1. The sun was condensed from dust clouds and the planets from what was left over. 2. That the sun was originally a binary system and an encounter occurred. 3. That it might have been a super-nova. 4. It might have been formed by slow accretion.

A question period followed and many interesting points were discussed.

E. E. Bridgen, *Recording Secretary*

# The Royal Astronomical Society of Canada

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